reason to be grateful for the efforts made by the Universities to extend these educational opportunities. And stimulus given to the teachers reacts most beneficially upon the schools and pupils under their care. In educational as in all work it is necessary to have patience in awaiting results. The best results of an improved system of primary or secondary education are not those which are the first to show themselves. And in course of time it is probable that the number of persons desiring to avail themselves of opportunities for continuing their education within easy reach of their own homes and in the leisure hours of life will steadily increase. In the circumstances of our own country, where momentous issues of Imperial policy constantly turn upon the popular vote, it is of high importance that we should encourage by all the means in our power the growth of educational organisations which are providing dispassionate instruction in the duties of modern citizenship and diffusing that kind of knowledge which is necessary to the formation of a discriminating judgment. We do not believe that it is possible to indoctrinate busy people with a systematic knowledge of a dozen or fifteen subjects, to understand any one of which would require a preparatory knowledge of many years. But it is possible to aid intelligent students in every rank of life to gain the elements, the gist, of liberal culture, and to obtain that insight into the vast complexity of human affairs which is the salutary safeguard of intellectual modesty and the best protection against hurried and partial judgments. It is in training and providing the teachers for this great and difficult work of adult popular education that the Universities are rendering one of their highest services to the country. By equipping and sending out these intellectual missionaries; men of high purpose and of high culture, they are really guiding a national movement. Let us not imagine that great educational enterprises realise themselves mechanically—that the merely fortuitous combinations of County Councils or other public authorities will suffice to secure all that is wanted in the training of citizens for citizenship. Material aid of this kind is indispensable. It is a mark of local interest, it secures the further development of that local interest. But by itself it is insufficient. What is really indispensable is leadership. The man, or group of men, must be forthcoming who, in each centre of population, will take the lead and guide the various forces which are at our disposal into wisely-chosen channels of systematic effort. And it is one of the highest duties of the Universities to train and to send forth such men, to give them moral support in their difficult labours, and to attach to their enterprise the weight of academic prestige.

SOME CONDITIONS AFFECTING GEYSER ERUPTION.[1]

The Influence of Hydrostatic Pressure.

BOTH field observation and experiment have contributed to our present knowledge of the physical causes of geyser eruption. The natural history of geyser regions has been summarised by Weed (*School of Mines Quarterly*, New York, 1890, vol. xi. No. 4, p. 289), and the experimental work by Andreæ (*Neues Jahrbuch für Min. Geol. und Pal.*, 1893, Bd. ii. p. 1). Weed concludes that geysers occur only in acid volcanic rocks, and along natural drainage lines where meteoric waters accumulate for discharge. The source of heat is conceived to be escaping hot vapours from slowly cooling lavas, the only known geysers occurring in regions of recent volcanic activity. New geysers originate by the opening of new waterways along fissure planes in the rock, and such new orifices of overflow are continually forming to compensate the diminution in activity of older vents. The cause of the intermittent spouting which distinguishes the typical geyser was originally stated by Bunsen (Tyndall: "Heat as a Mode of Motion"; Appleton, 1888, p. 168); the boiling-point of water rises with increased pressure, hence decreases from the lower end of a water-filled tube upward.. If water of a lower stratum, nearly, but not quite, at the boiling point, be lifted by the entrance of steam from below to a level of less pressure and lower boiling point, "the heat which it possesses is in excess of that necessary to make it boil. This excess of heat is instantly applied to the generation of steam: the column is lifted higher, and the water below is further relieved. More steam is generated, and from the middle downwards the mass suddenly bursts into ebullition. The water above, mixed with steam-clouds, is projected into the atmosphere. . . ." (Tyndall, *l.c.*, pp. 169-170).

The accuracy of Bunsen's theory was early confirmed by experiment; and the only mechanism necessary to produce geyser eruption is a tube filled with water, open above and heated below. Many further experiments have been made, however, with a view to explaining the variations observed in the period and interval of geyser eruptions, the relative amount of steam and water, and the effect of artificial stmulants in hastening eruption. Andreæ's experiments were directed toward the imitation of Peale's ("U.S. Geological Survey of the Territories, 1884," vol. xii. part 2) types, a classification based on the form of the basins and the relation of the periods of steam and water in the eruption. It is noteworthy that in most of these experiments, the apparatus recommended has an open basin above, which retains the water thrown out and permits it to *flow back* into the geyser tube.

In Peale's classification no mention is made of the nature of the geyser-spring during the interval of quiescence; in some cases there is continuous overflow or discharge, in others there is no overflow except during eruption. As it may be shown that this fact of the presence or absence of hydrostatic pressure at the geyser vent has an important bearing on the conditions of eruption, the writer would suggest a classification based on this very simple distinction; it is a singular fact that in the published descriptions of geysers this point has been frequently overlooked. If geyser waters represent meteoric drainage, they are affected by the laws of hydrostatic equilibrium. In such case a tube continuously overflowing is in a distinctly different class from one which throws off its waters to join the superficial drainage to the sea only during the period of its occasional or intermittent discharge. The first case is represented by such a geyser spring as "Excelsior," in the Yellowstone Park, a violently boiling cauldron in the hill slope, continually discharging vast volumes of water into the pond below, which in turn drains into the Firehole River; the Great Geyser of Iceland, and the Rotomahana Geyser (destroyed by the Tarawera eruption in 1886) of New Zealand are other types of the continually overflowing class. "Old Faithful" is the type of the second class; its waters may be seen in violent ebullition a few feet below the orifice of the vent, but overflow takes place only during eruption.

Any apparatus designed to imitate accurately either of these must be provided with a supply reservoir having subterranean connection with the geyser tube, by which water may siphon in to replace that discharged. Obviously this replacement takes place in nature: if the water, as asserted, is meteoric, and governed by the same laws that determine the loci of springs, the natural method of such replacement is by the action of gravity. In the case of Excelsior, this subterranean compensation is continuous; the effective head of water at the orifice of exit is fairly constant: in the case of Old Faithful the water-column is in equilibrium, and replacement occurs only after each eruption, when this equilibruim has been disturbed by the ejection of the column.

Experimental Demonstration.

A simple device to illustrate this process was described by G. Wiedemann (*Wiedemann's Annalen*, xv., 1882, p. 173) and mentioned by Andreæ (*l.c.*, p. 4). Wiedemann made no geological comparisons, the apparatus having been constructed for class-room illustration in physics; and most of the geological experimenters have used back-flow apparatus, without supply reservoirs. The essential parts of Wiedemann's apparatus are a water-column heated below, and a supply-tube entering this column and connecting it with a reservoir of cooler, superficial waters. When the excess of steam generated has thrown out the main column, cooler water filters in through the supply tube, and fills the geyser tube to the level of the reservoir. For effective and regularly repeated geyser eruptions, the reservoir level must be maintained a little below the height of the mouth of the geyser tube.

The accompanying figure illustrates Wiedemann's apparatus, as it has been used by the writer. The dimensions are as follows: capacity of each flask, one quart; length of main geyser tube 4 feet, diameter (outside) 5/16 inches; diameter of basin 2 feet; the bottom flares funnel-wise from the centre slightly, and is provided with a ¼-inch outlet tube *t*. The lower flask rests on a sheet of wire-netting over the flame of a four- or six-tube Bunsen burner, and the basin and reservoir bottle are supported above on a wooden frame. The basin is of zinc, and may be raised or lowered so that the mouth of the geyser tube is flush with the bottom of the basin or raised above it as shown. The supply tube is recurved slightly at the bottom of the flask, so that the cold jets which siphon in from the reservoir will not be directed against the glass wall of the flask and break it. The reservoir bottle is connected by rubber tubing with the supply tube, so that the bottle may be freely raised or lowered to various levels indicated by the dotted lines *a*, *b* and *c*.

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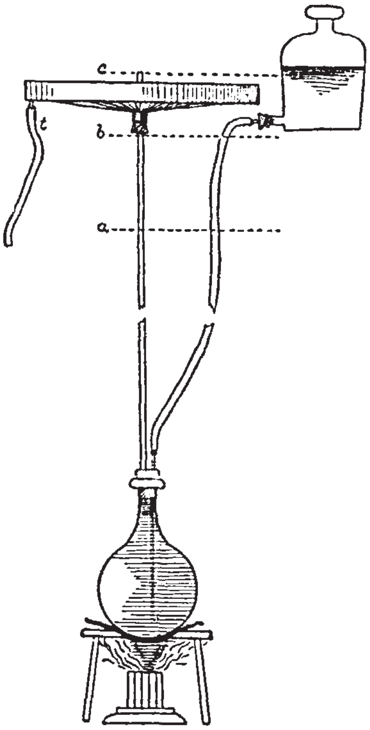
[1] By T. A. Jaggar, jun. (Abridged from the *American Journal of Science*, May.)

Experiment 1.—"*Old Faithful*" *Type.*

When heat is applied below, the reservoir level being at *a*, fter about 14 minutes an eruption takes place, characterised by violent ebullition in the flask below, ejection of the water-column to a height of about 4 feet and of a mixture of steam and water for a few seconds longer; then the water-level in the reservoir is seen to fall suddenly, a stream is seen to be flowing into the lower flask from the curved tip of the supply-tube, the cooling of the base of the column is accompanied by ondensation of steam and downward suction, the water rises to level *a* again and a period of repose fellows. It should be noted that if the level of the cooler water in the reservoir is at *a*, the expanded warmer water in the geyser tube is somewhat above *a*. The process described is repeated at regular intervals of about 1½ minutes, the duration of each eruption being about 20 seconds. If the water in the reservoir be not renewed, it gradually becomes warmer and the intervals are of shorter duration. In this case, or with the reservoir level somewhat higher, as at *b*, and the geyser mouth raised above the basin, as shown in the figure, we have in miniature the conditions of "Old Faithful."



Experiment 2.—"*Excelsior*" *Type.*

The conditions are altered if we raise the reservoir level to the point shown in the figure, namely, just above the height of the geyser mouth (*c*). In such case there is continuous overflow of the hot water, and if the outlet tube *t* be left open, this will continually flow off this over-flow must be constantly compensated at the supply tube by cooler water from the reservoir, so that the water in the flask never reaches the boiling point. If the water-level of the reservoir be maintained constant, this circulation will continue indefinitely, and in such case there will be a dome-shaped mass of hot water continually boiling up and overflowing at the geyser's mouth, as in the case of the Excelsior Geyser. Now at this stage, if the water-level in the reservoir be allowed to sink under the drain upon it, it may fall to a level six inches below *c*, without interrupting the continuous overflow; in other words, it may fall back to the *b* level, and yet the geyser will continue to act as a boiling spring, without entering into an eruptive phase. The cause of this is to be found in the differential expansion of the water noted above, and a convectional upflow which acts as a driving-power even against a reversed head, after overflow has once been established.[1] The overflow tube *t* may at this stage be led into the reservoir at the *b* level; this establishes a permanent circulation, the only loss being by evaporation. With the diminution in pressure if the level of the reservoir sinks, there is a tendency towards diminished inflow of cooler water at the supply-tube; this implies rise in temperature of the water at the base of the geyser-column, which tends to augment both volumetric expansion and convectional velocity. Hence there is here a critical point where the hydrothermal and hydrostatic forces are in very delicate equilibrium; if the reservoir is lowered an inch, the overflow decreases, ebullition takes place below, and an eruption of extraordinary violence takes place. The same effect is at once produced by placing the glass stopper in the reservoir bottle, and so checking the atmospheric pressure. When the mouth of the geyser-tube is flush with the bottom of the basin, an eruption may be induced by stopping the overflow tube *t* and permitting the water-level to rise in the basin, thus augmenting the pressure on the geyser-column. Eruptions once started will continue intermittently, if the hydrostatic conditions are maintained constant; if, however, the water-level of the reservoir again rises to a point where continuous overflow is possible at the geyser's mouth, the eruptions will cease and a hot-spring phase will follow.

Field Application of the Results of Experiment.

The two simple experiments described, when compared with the facts of nature, account for the most essential variations observed in the phenomena of geyser eruption. Both are methods of draining the reservoir—the one continuous, the other spasmodic. In the same way the geyser-springs drain off the superficial waters that accumulate from the abundant rainfall of the Yellowstone Plateau. The "Excelsior" cauldron is stated by Hague ("Geol. History of the Yellowstone National Park, *Transactions* Am. Inst. of Min. Eng., vol. xvi., 1888) to discharge constantly into the Firehole River 4400 gallons of boiling water per minute, "and there is no evidence that this amount has varied within the last two or three years (1887)." Weed (*l.c.*) has estimated, on the moderate assumption that one-third of the eruption-column of Old Faithful is water, that 3000 barrels are thrown off at each eruption. Here we have examples of continuous and spasmodic drainage methods, both sending their waters eventually to the Madison River, and re-supplied from a local source.

The geyser basins are topographic hollows, which supply vents for the meteoric waters accumulated in fissures of the decomposed rhyolite. These waters are heated by vapours escaping from the only partially cooled deeper lavas, and are escaping in the form of springs and geysers. In the springs the overflow is occasioned by hydrostatic pressure; in the geysers it is permitted by occasional violent discharge. The transition from one phase to the other may readily be induced, as shown in Experiment 2, by very slight changes in the hydrostatic pressure, *i.e.* variations in the mean level of ground-water (Grundwasserspiegel), or in the local head for any specific case. The head of water may be modified at either the source (supply reservoir) or the orifice of exit; head is diminished by lowering the reservoir through formation of new outlets or through decreased supply, or by building up a cone around the geyser tube. Conversely the head of water may be increased by excessive supply (rainfall) at the reservoir, by clogging of outlets, or by the water finding a new vent at a lower level.

Soaping Geysers.

It has long been known that by artificially confining the steam in small-mouthed geysers of high surface temperature, eruption may be brought about prematurely. In Iceland the Strokr is thus stimulated by dumping into the neck of the funnel large pieces of turf. In the Yellowstone district, it has been found that a small amount of soap or lye added to the geyser water will frequently hasten eruption. This is explained by Hague ("Soaping Geysers," *Trans. Amer. Inst. Min. Eng.*, vol. xvii., 1889, p. 546) as due to the increased viscosity of the liquid. "Viscosity must tend to the retention of steam within the basin and . . . explosive liberation must follow . . . Viscosity in these hot springs must also tend to the formation of bubbles and foam when the steam rises to the surface, and this in turn aids to bring about the explosive action, followed by a relief of pressure, and thus to hasten the final and more powerful display." Graham (*American Journal of Science*, January 1893, p. 54), as a result of experiments with an artificial geyser, agrees that viscosity has much to do with the confinement of steam, but questions the influence of bubbles and foam.

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[1] Such convection currents gain no momentum without overflow, hence at the *a* level convection played no essential part in the phenomena observed.

Experiment 3.—*The Effect of Soap.*

The apparatus was arranged to give regular eruptions as in Experiment 1, with the geyser-tube flush with the bottom of the basin and the water maintained about an inch deep in the basin without overflow. A small quantity of fine shavings of Ivory soap was thrown into the basin: these gradually dissolved and the milky solution was, after several eruptions, sucked into the flask below. The occasional steam-bubbles, which, in pure water, rise rapidly through the geyser-tube and escape at the surface during the intervals between eruptions, were less numerous, very small, and slower in their upward movement through the soapy solution; after five or six eruptions it became evident that the intervals were somewhat shorter (averaging 1 min. 20–30 seconds, instead of 1 min. 30–40 seconds), and the periods very noticeably longer (40–45 seconds, instead of 20 seconds). The ebullition in the flask was more violent than in the case of pure water, and columns of fine bubbles accumulated in the geyser-tube, only to be ejected with a violent sputter and give place to a new accumulation. It was evident that these accumulated myriads of tiny steam bubbles, confined within the tube and adhering to the walls of the tube, formed a cushion opposing considerable resistance to pressure from below.

After the diffusion of the soapy solution had become general, the reservoir (and consequently the geyser-column) was lowered to the level *a*; the intervals were at once shortened to an average of about one minute, in consequence of the rapid accumulation at the surface of the column and *within the tube* of the cushion of steam bubbles. So resistant is this cushion, that as it grows by the addition of new bubbles rising from below, the water column is actually depressed, down to the neck of the flask; here a point is reached where the frictional resistance of the froth cushion and the hydrostatic pressure are balanced. A further accumulation of steam forces up the column of foam, release of pressure permits the water to burst into violent ebullition, and an eruption takes place. From this it would appear that in those geysers where the tube is small, the growth of a cushion of steam soap-bubbles may play a very important part in accelerating the development of eruptive conditions.

Summary.

(1) Geysers and boiling springs are subject to the laws of hydrostatic pressure, in common with other springs.

(2) In a geyser-spring, overflow once established may be maintained by convection even against a reversed head; this leads to a critical point in the spring's mode of discharge.

(3) In this condition, with a constant source of heat, very slight changes in the local head are sufficient to induce a change in the nature of a geyser-spring's mode of action. Such change in the head may be caused by variation in rainfall, by building up a sinter cone by forcing new outlets at lower levels, or by clogging of old conduits.

(4) Geyser basins afford drainage channels for meteoric waters. The drainage takes place by either continuous overflow (hot springs) or spasmodic eruption (geysers). Both types, as well as transitional forms, are represented in the Yellowstone Park.

(5) In general, those geysers which are irregular in their eruptions have continuously overflowing vents; and the most regular geysers have confined waters, which overflow only during eruption. This is explained by the fact that the overflowing vents are under hydrostatic pressure, cooler water from lateral ducts is continually replacing that which flows off, and the ebullition necessary to produce eruption is thus prevented; eruption can only take place in the seasons of minimal inflow of cooler water, when the heat is in excess. Where the water is confined, on the other hand, and the supply of heat constant, cooler water rushes in only after each eruption, and a definite interval is required to bring it to the boiling point at the base of the column. Overflowing and confined springs should be distinguished in any description or classification of geysers.

(6) For the artificial stimulus of geyser eruption, an important effect of the bubble forming alkalies, in small tubes, is the initial depression of the water-column by the growth of a confined cushion of minute steam bubbles. The release of pressure induced by the final ejection of the froth column causes eruption.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

DR. MERRILL E. GATES has resigned the presidency of Amherst College.

THE following appointments are announced:—Dr. Charles Harrington to be assistant professor of hygiene, and Dr. Franz Pfaff to be instructor in pharmacology and physiological chemistry in Harvard University; Mr. R. A. Emerson to be assistant professor of horticulture at the University of Nebraska.

Science announces the following gifts for educational and scientific purposes:—50,000 dollars, from a source kept secret, to Amherst College, for an academic hall in honour of President Seelye; 20,000 dollars from Mr. H. L. Higginson, treasurer of the J. W. and Belinda Randall Charities Corporation of Monson, Mass., for the erection of a building, or as a permanent fund in connection with the University of Virginia. *Science* also states that two conditional gifts of 50,000 dollars, offered by Dr. D. K. Pearsons, have been secured by the colleges collecting the additional sums required. The endowment of Beloit College is thus increased by 200,000 dollars, and that of Mt. Holyoke College by 150,000 dollars.

THE *Calcutta Gazette* reports that representatives of La Martinière and Doveton Colleges have been appointed to consider the advisability or otherwise of the amalgamation of the two institutions. It appears that for many years these two colleges carried on with efficiency, and at a standard which compared favourably with corresponding schools in England, a large portion of the work of secondary education in Calcutta; but in recent years both La Martinière and Doveton, from causes over which they have had little control, have fallen behind in the race for up-to-date education. Owing to the keen competition of newly-opened hill schools, and the consequent loss of scholars and fees, also owing to heavy reduction in interest on the capital invested in Government securities, these colleges have not been able to keep pace with the requirements of modern education; while, on the other hand, they have been handicapped by heavy expenditure on the up-keep of extensive buildings and the payment of large sums in municipal rates and taxes. To remedy this state of affairs, which every year becomes more serious and pressing, the amalgamation of the two institutions has been suggested, in the hope that the result would be a considerable decrease in expenditure and a consequent gain in discipline and efficiency. It is fully recognised that there are difficulties in the way of the realisation of this scheme, but the Lieutenant-Governor sees no reason to believe them insurmountable. The aims and objects of the two institutions are almost identical, and it is hoped that petty differences of detail may not be allowed to stand in the way of arriving at a common understanding as to some broad scheme of amalgamation on lines which, by uniting the resources of the two colleges, will enable them to provide that standard of European education which it was the intention of their founders to give, but which under existing conditions it is practically impossible that either college alone can supply from its unaided resources.

SCIENTIFIC SERIALS.

THE *Mathematical Gazette*, issued under the auspices of the Mathematical Association, continues to maintain its interesting collection of notes and solutions to problems. The June number, recently issued, contains, in addition to these notes, papers by Mr. H. B. Billups on the connection between the inscribed and escribed circles of a triangle, and by Mr. R. F. Muirhead on relative motion. We should be glad to see more articles in the *Gazette* dealing with questions of general principle, rather than